FIG.12

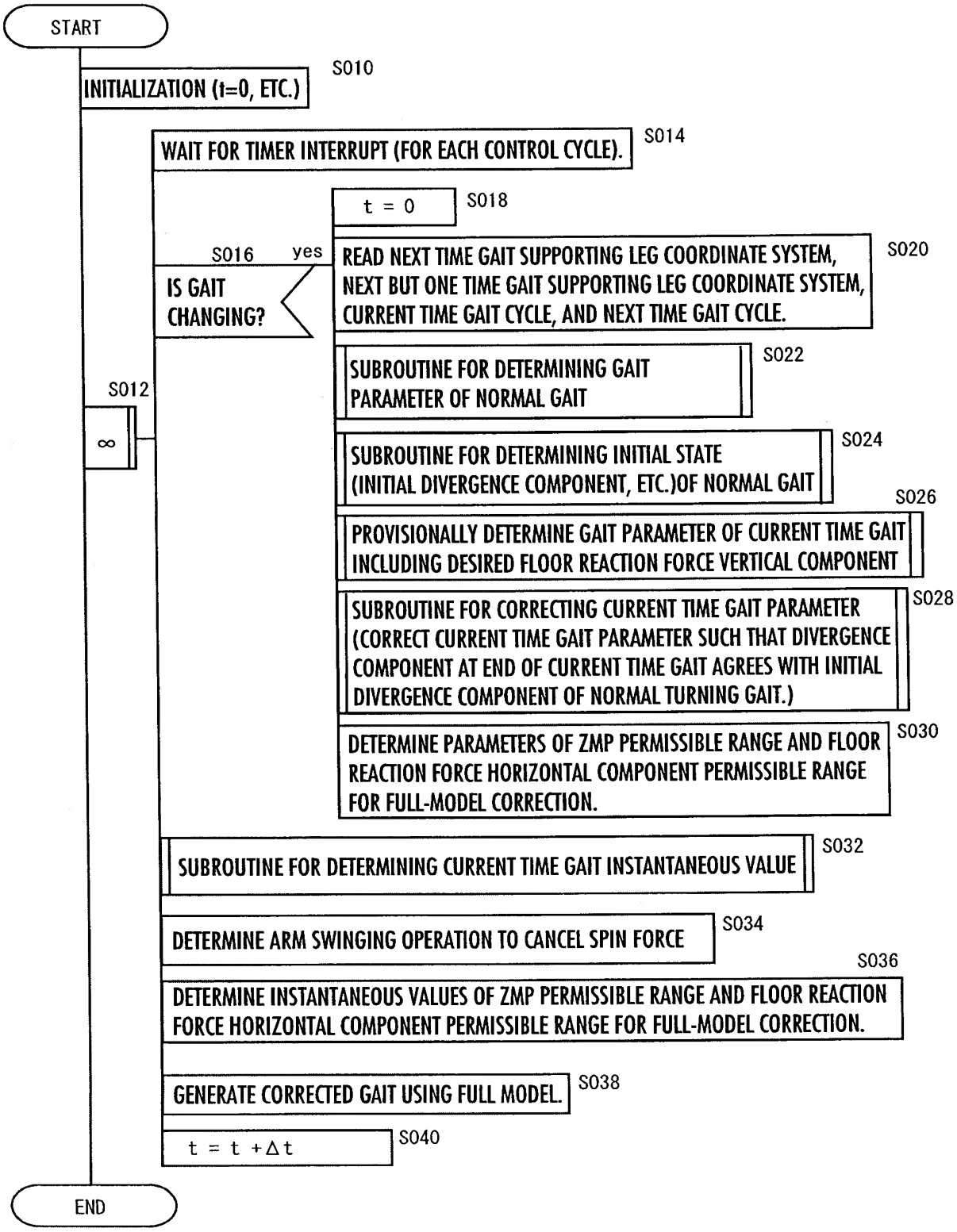

START
INITIALIZATION (t=0, ETC.)
S010
WAIT FOR TIMER INTERRUPT (FOR EACH CONTROL CYCLE).
S014
t = 0
S018
S016
yes
IS GAIT CHANGING?
READ NEXT TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, NEXT BUT ONE TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, CURRENT TIME GAIT CYCLE, AND NEXT TIME GAIT CYCLE.
S020
SUBROUTINE FOR DETERMINING GAIT PARAMETER OF NORMAL GAIT
S022
S012
∞
SUBROUTINE FOR DETERMINING INITIAL STATE (INITIAL DIVERGENCE COMPONENT, ETC.)OF NORMAL GAIT
S024
S026
PROVISIONALLY DETERMINE GAIT PARAMETER OF CURRENT TIME GAIT INCLUDING DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT
SUBROUTINE FOR CORRECTING CURRENT TIME GAIT PARAMETER (CORRECT CURRENT TIME GAIT PARAMETER SUCH THAT DIVERGENCE COMPONENT AT END OF CURRENT TIME GAIT AGREES WITH INITIAL DIVERGENCE COMPONENT OF NORMAL TURNING GAIT.)
S028
DETERMINE PARAMETERS OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
S030
SUBROUTINE FOR DETERMINING CURRENT TIME GAIT INSTANTANEOUS VALUE
S032
DETERMINE ARM SWINGING OPERATION TO CANCEL SPIN FORCE
S034
S036
DETERMINE INSTANTANEOUS VALUES OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
GENERATE CORRECTED GAIT USING FULL MODEL.
S038
t = t +Δt
S040
END

FIG.14

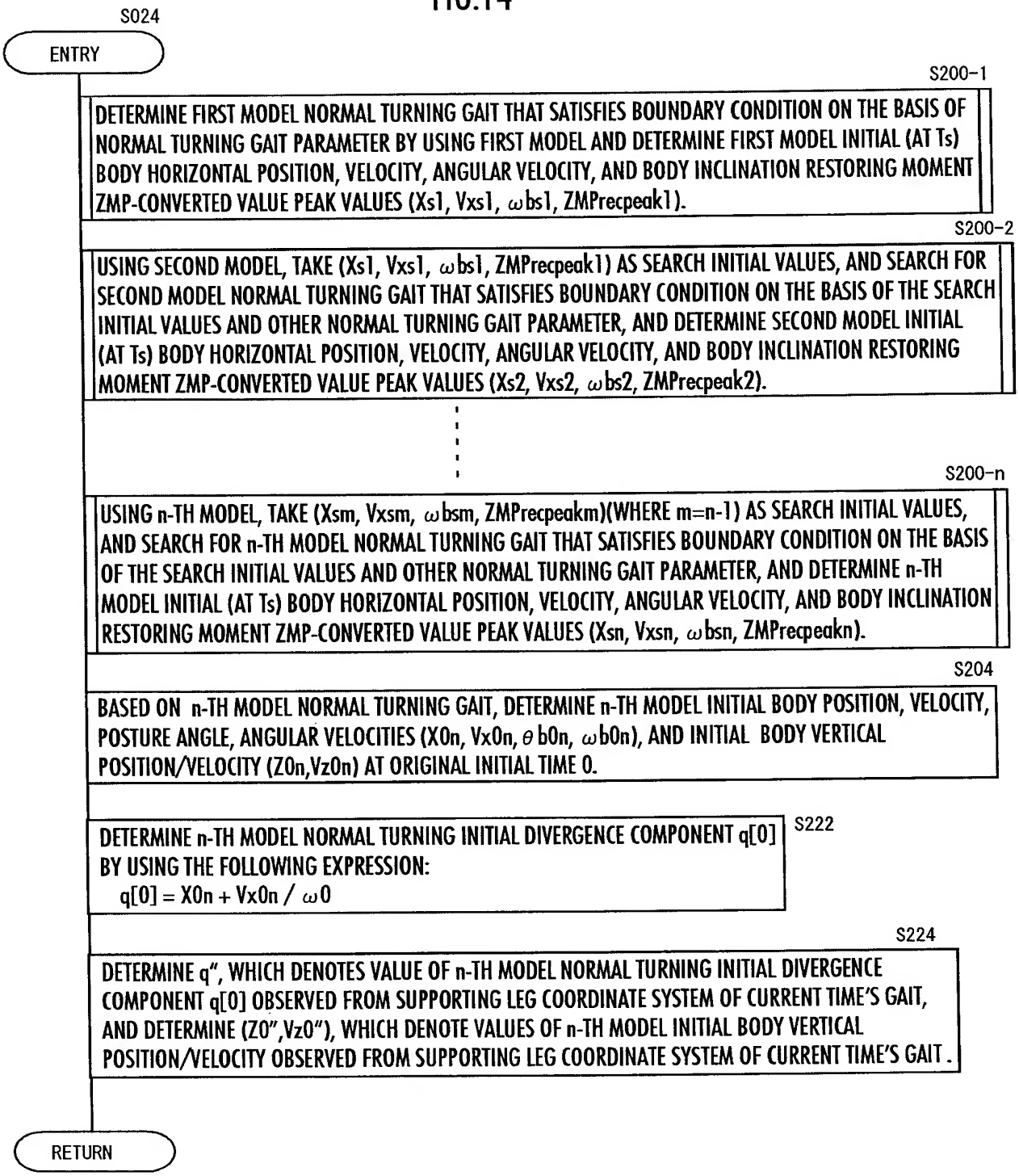

S024
ENTRY
S200-1
DETERMINE FIRST MODEL NORMAL TURNING GAIT THAT SATISFIES BOUNDARY CONDITION ON THE BASIS OF NORMAL TURNING GAIT PARAMETER BY USING FIRST MODEL AND DETERMINE FIRST MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUES (Xs1, Vxs1, ωbs1, ZMPrecpeak1).
S200-2
USING SECOND MODEL, TAKE (Xs1, Vxs1, ωbs1, ZMPrecpeak1) AS SEARCH INITIAL VALUES, AND SEARCH FOR SECOND MODEL NORMAL TURNING GAIT THAT SATISFIES BOUNDARY CONDITION ON THE BASIS OF THE SEARCH INITIAL VALUES AND OTHER NORMAL TURNING GAIT PARAMETER, AND DETERMINE SECOND MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUES (Xs2, Vxs2, ωbs2, ZMPrecpeak2).
S200-n
USING n-TH MODEL, TAKE (Xsm, Vxsm, ωbsm, ZMPrecpeakm)(WHERE m=n-1) AS SEARCH INITIAL VALUES, AND SEARCH FOR n-TH MODEL NORMAL TURNING GAIT THAT SATISFIES BOUNDARY CONDITION ON THE BASIS OF THE SEARCH INITIAL VALUES AND OTHER NORMAL TURNING GAIT PARAMETER, AND DETERMINE n-TH MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUES (Xsn, Vxsn, ωbsn, ZMPrecpeakn).
S204
BASED ON n-TH MODEL NORMAL TURNING GAIT, DETERMINE n-TH MODEL INITIAL BODY POSITION, VELOCITY, POSTURE ANGLE, ANGULAR VELOCITIES (X0n, Vx0n, θb0n, ωb0n), AND INITIAL BODY VERTICAL POSITION/VELOCITY (Z0n,Vz0n) AT ORIGINAL INITIAL TIME 0.
DETERMINE n-TH MODEL NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] BY USING THE FOLLOWING EXPRESSION:
q[0] = X0n + Vx0n / ω0
S222
S224
DETERMINE q", WHICH DENOTES VALUE OF n-TH MODEL NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME'S GAIT, AND DETERMINE (Z0",Vz0"), WHICH DENOTE VALUES OF n-TH MODEL INITIAL BODY VERTICAL POSITION/VELOCITY OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME'S GAIT.
RETURN

FIG.15

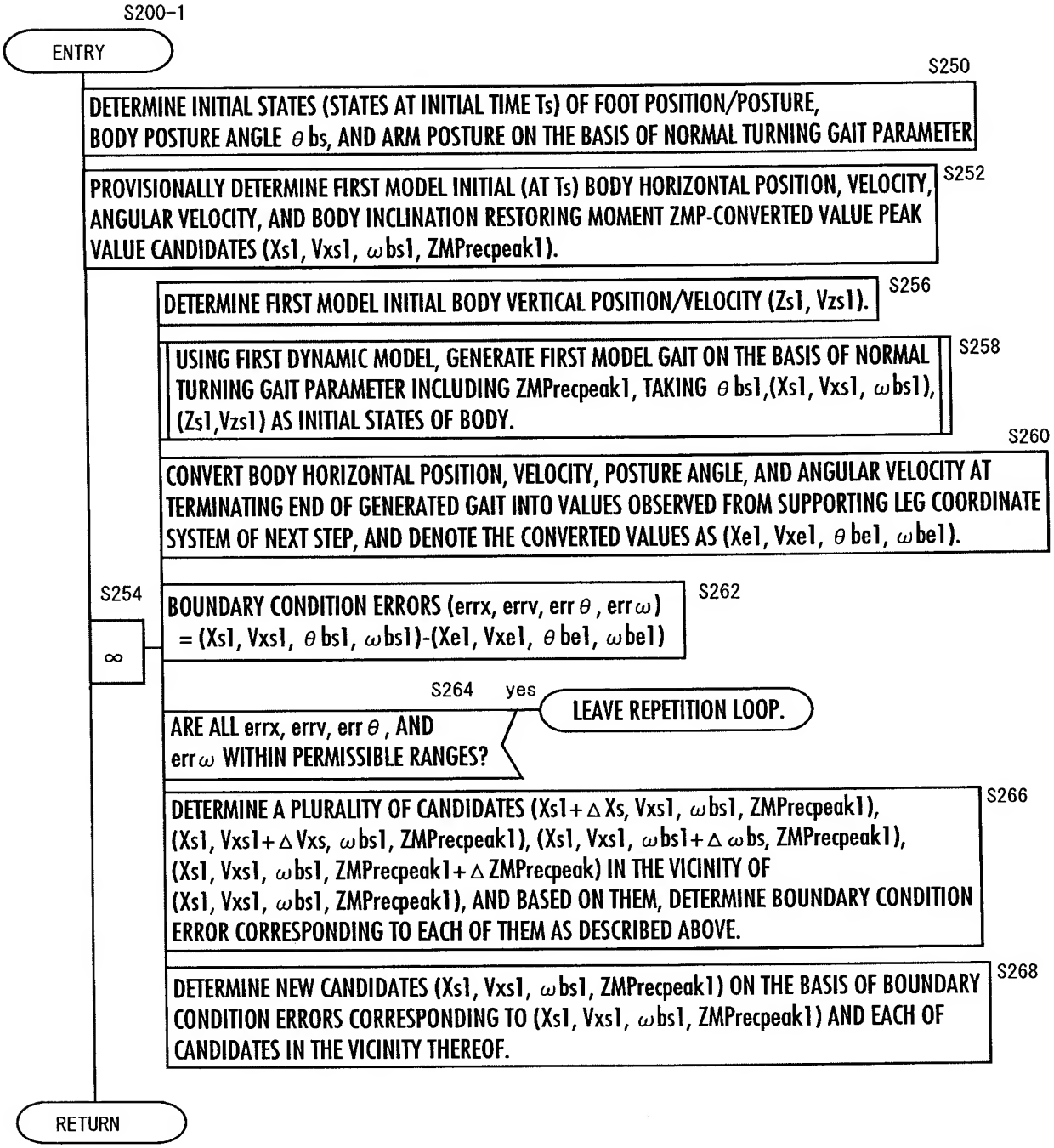

S200-1
ENTRY
S250
DETERMINE INITIAL STATES (STATES AT INITIAL TIME Ts) OF FOOT POSITION/POSTURE, BODY POSTURE ANGLE θbs, AND ARM POSTURE ON THE BASIS OF NORMAL TURNING GAIT PARAMETER
S252
PROVISIONALLY DETERMINE FIRST MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (Xs1, Vxs1, ωbs1, ZMPrecpeak1).
S256
DETERMINE FIRST MODEL INITIAL BODY VERTICAL POSITION/VELOCITY (Zs1, Vzs1).
S258
USING FIRST DYNAMIC MODEL, GENERATE FIRST MODEL GAIT ON THE BASIS OF NORMAL TURNING GAIT PARAMETER INCLUDING ZMPrecpeak1, TAKING θbs1,(Xs1, Vxs1, ωbs1), (Zs1,Vzs1) AS INITIAL STATES OF BODY.
S260
CONVERT BODY HORIZONTAL POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY AT TERMINATING END OF GENERATED GAIT INTO VALUES OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF NEXT STEP, AND DENOTE THE CONVERTED VALUES AS (Xe1, Vxe1, θbe1, ωbe1).
S254
∞
S262
BOUNDARY CONDITION ERRORS (errx, errv, errθ, errω) = (Xs1, Vxs1, θbs1, ωbs1)-(Xe1, Vxe1, θbe1, ωbe1)
S264
yes
ARE ALL errx, errv, errθ, AND errω WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
S266
DETERMINE A PLURALITY OF CANDIDATES (Xs1+ΔXs, Vxs1, ωbs1, ZMPrecpeak1), (Xs1, Vxs1+ΔVxs, ωbs1, ZMPrecpeak1), (Xs1, Vxs1, ωbs1+Δωbs, ZMPrecpeak1), (Xs1, Vxs1, ωbs1, ZMPrecpeak1+ΔZMPrecpeak) IN THE VICINITY OF (Xs1, Vxs1, ωbs1, ZMPrecpeak1), AND BASED ON THEM, DETERMINE BOUNDARY CONDITION ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S268
DETERMINE NEW CANDIDATES (Xs1, Vxs1, ωbs1, ZMPrecpeak1) ON THE BASIS OF BOUNDARY CONDITION ERRORS CORRESPONDING TO (Xs1, Vxs1, ωbs1, ZMPrecpeak1) AND EACH OF CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.16

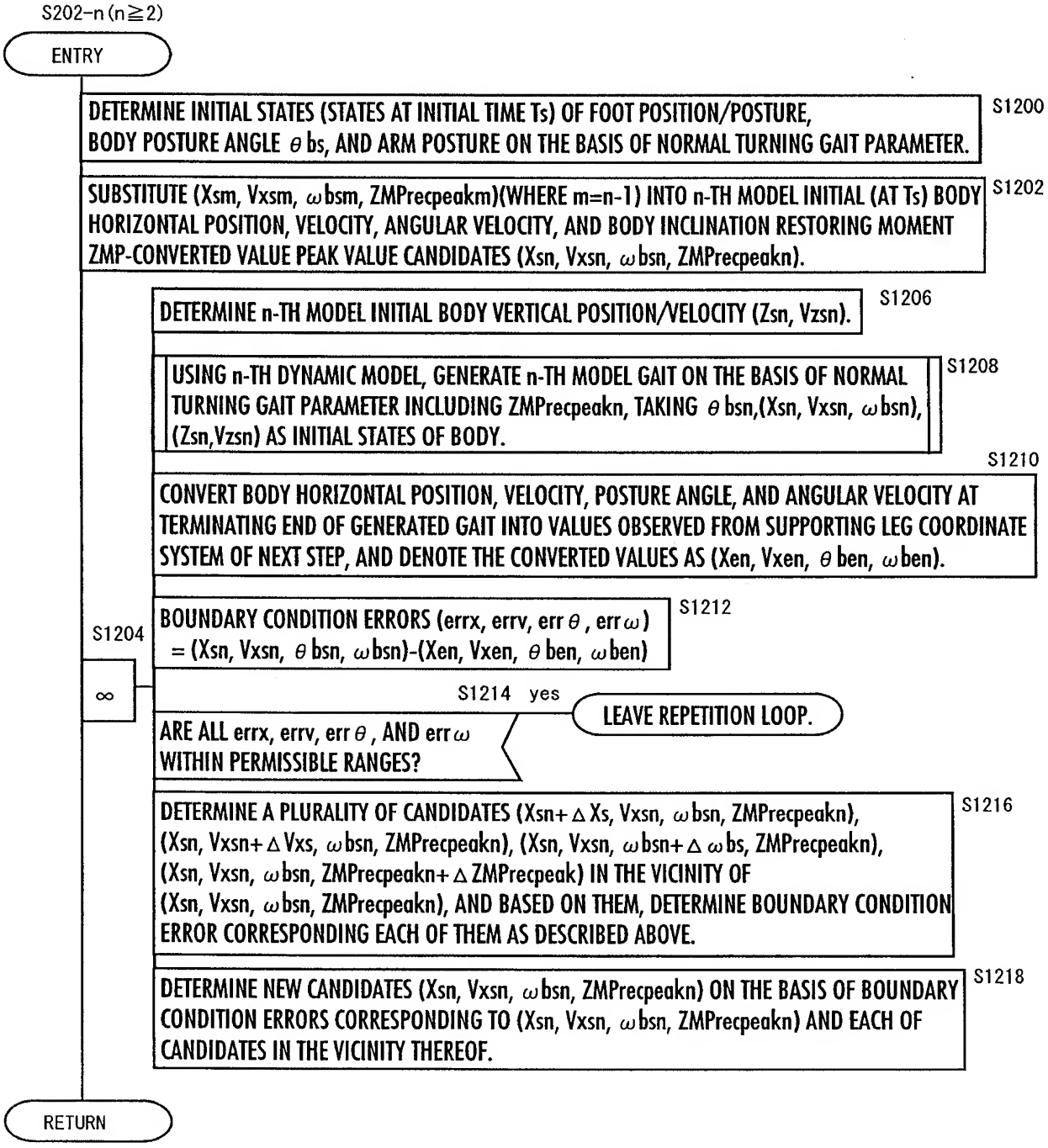

S202-n (n≧2)
ENTRY
DETERMINE INITIAL STATES (STATES AT INITIAL TIME Ts) OF FOOT POSITION/POSTURE, BODY POSTURE ANGLE θbs, AND ARM POSTURE ON THE BASIS OF NORMAL TURNING GAIT PARAMETER.
S1200
SUBSTITUTE (Xsm, Vxsm, ωbsm, ZMPrecpeakm)(WHERE m=n-1) INTO n-TH MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (Xsn, Vxsn, ωbsn, ZMPrecpeakn).
S1202
DETERMINE n-TH MODEL INITIAL BODY VERTICAL POSITION/VELOCITY (Zsn, Vzsn).
S1206
USING n-TH DYNAMIC MODEL, GENERATE n-TH MODEL GAIT ON THE BASIS OF NORMAL TURNING GAIT PARAMETER INCLUDING ZMPrecpeakn, TAKING θbsn,(Xsn, Vxsn, ωbsn), (Zsn,Vzsn) AS INITIAL STATES OF BODY.
S1208
CONVERT BODY HORIZONTAL POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY AT TERMINATING END OF GENERATED GAIT INTO VALUES OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF NEXT STEP, AND DENOTE THE CONVERTED VALUES AS (Xen, Vxen, θben, ωben).
S1210
BOUNDARY CONDITION ERRORS (errx, errv, errθ, errω) = (Xsn, Vxsn, θbsn, ωbsn)-(Xen, Vxen, θben, ωben)
S1212
S1204
∞
S1214
yes
ARE ALL errx, errv, errθ, AND errω WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
DETERMINE A PLURALITY OF CANDIDATES (Xsn+ΔXs, Vxsn, ωbsn, ZMPrecpeakn), (Xsn, Vxsn+ΔVxs, ωbsn, ZMPrecpeakn), (Xsn, Vxsn, ωbsn+Δωbs, ZMPrecpeakn), (Xsn, Vxsn, ωbsn, ZMPrecpeakn+ΔZMPrecpeak) IN THE VICINITY OF (Xsn, Vxsn, ωbsn, ZMPrecpeakn), AND BASED ON THEM, DETERMINE BOUNDARY CONDITION ERROR CORRESPONDING EACH OF THEM AS DESCRIBED ABOVE.
S1216
DETERMINE NEW CANDIDATES (Xsn, Vxsn, ωbsn, ZMPrecpeakn) ON THE BASIS OF BOUNDARY CONDITION ERRORS CORRESPONDING TO (Xsn, Vxsn, ωbsn, ZMPrecpeakn) AND EACH OF CANDIDATES IN THE VICINITY THEREOF.
S1218
RETURN

FIG.20

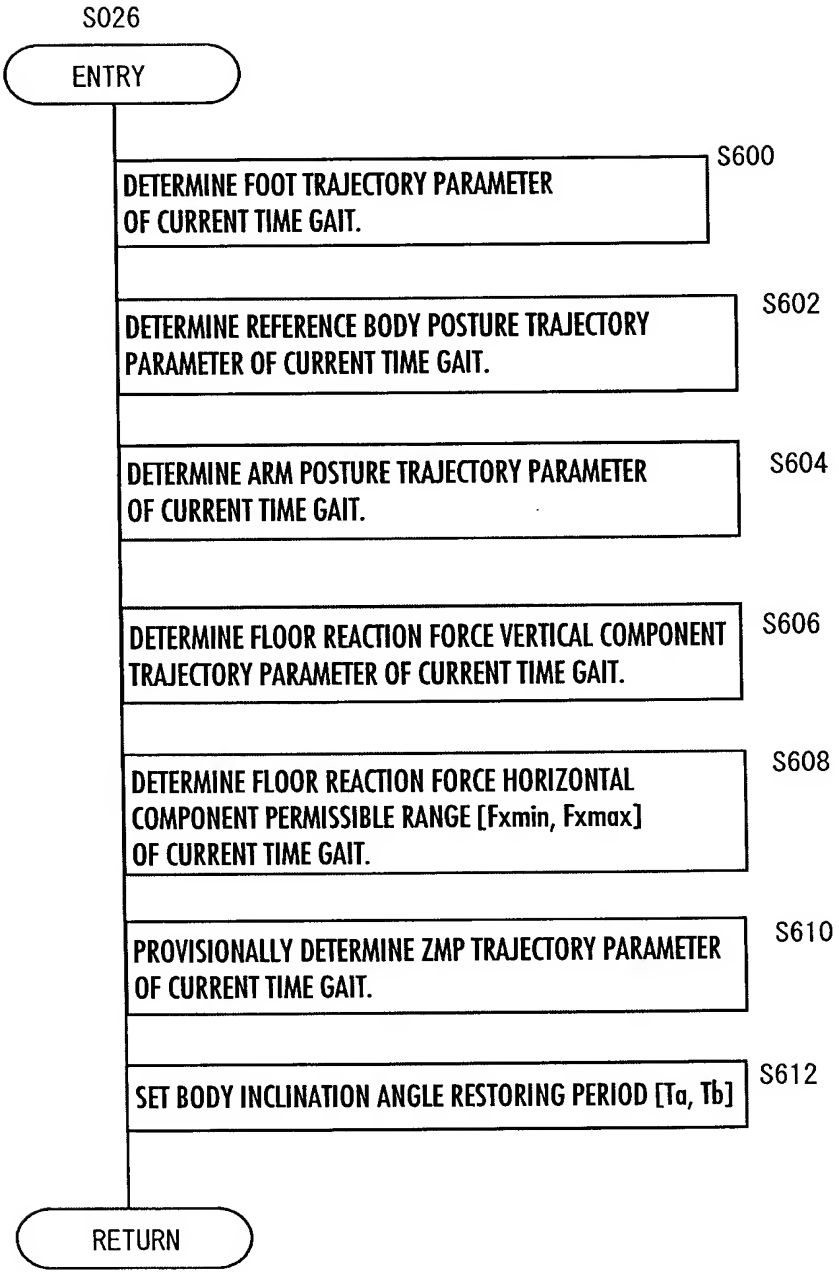
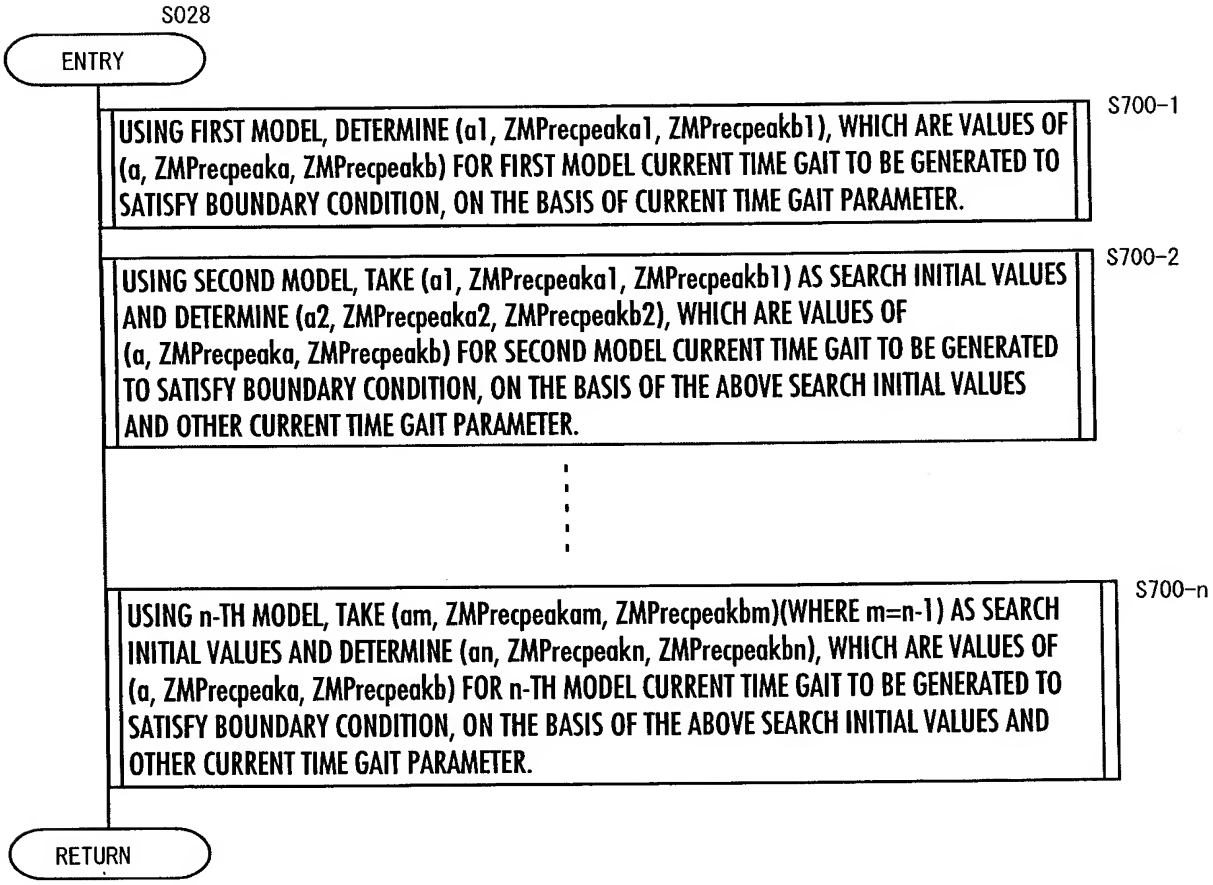

S026
ENTRY
DETERMINE FOOT TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S600
DETERMINE REFERENCE BODY POSTURE TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S602
DETERMINE ARM POSTURE TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S604
DETERMINE FLOOR REACTION FORCE VERTICAL COMPONENT TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S606
DETERMINE FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE [Fxmin, Fxmax] OF CURRENT TIME GAIT.
S608
PROVISIONALLY DETERMINE ZMP TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S610
SET BODY INCLINATION ANGLE RESTORING PERIOD [Ta, Tb]
S612
RETURN

FIG.21


S028
ENTRY
USING FIRST MODEL, DETERMINE (a1, ZMPrecpeaka1, ZMPrecpeakb1), WHICH ARE VALUES OF (a, ZMPrecpeaka, ZMPrecpeakb) FOR FIRST MODEL CURRENT TIME GAIT TO BE GENERATED TO SATISFY BOUNDARY CONDITION, ON THE BASIS OF CURRENT TIME GAIT PARAMETER.
S700-1
USING SECOND MODEL, TAKE (a1, ZMPrecpeaka1, ZMPrecpeakb1) AS SEARCH INITIAL VALUES AND DETERMINE (a2, ZMPrecpeaka2, ZMPrecpeakb2), WHICH ARE VALUES OF (a, ZMPrecpeaka, ZMPrecpeakb) FOR SECOND MODEL CURRENT TIME GAIT TO BE GENERATED TO SATISFY BOUNDARY CONDITION, ON THE BASIS OF THE ABOVE SEARCH INITIAL VALUES AND OTHER CURRENT TIME GAIT PARAMETER.
S700-2
USING n-TH MODEL, TAKE (am, ZMPrecpeakam, ZMPrecpeakbm)(WHERE m=n-1) AS SEARCH INITIAL VALUES AND DETERMINE (an, ZMPrecpeakn, ZMPrecpeakbn), WHICH ARE VALUES OF (a, ZMPrecpeaka, ZMPrecpeakb) FOR n-TH MODEL CURRENT TIME GAIT TO BE GENERATED TO SATISFY BOUNDARY CONDITION, ON THE BASIS OF THE ABOVE SEARCH INITIAL VALUES AND OTHER CURRENT TIME GAIT PARAMETER.
S700-n
RETURN

22 / 27

FIG.22

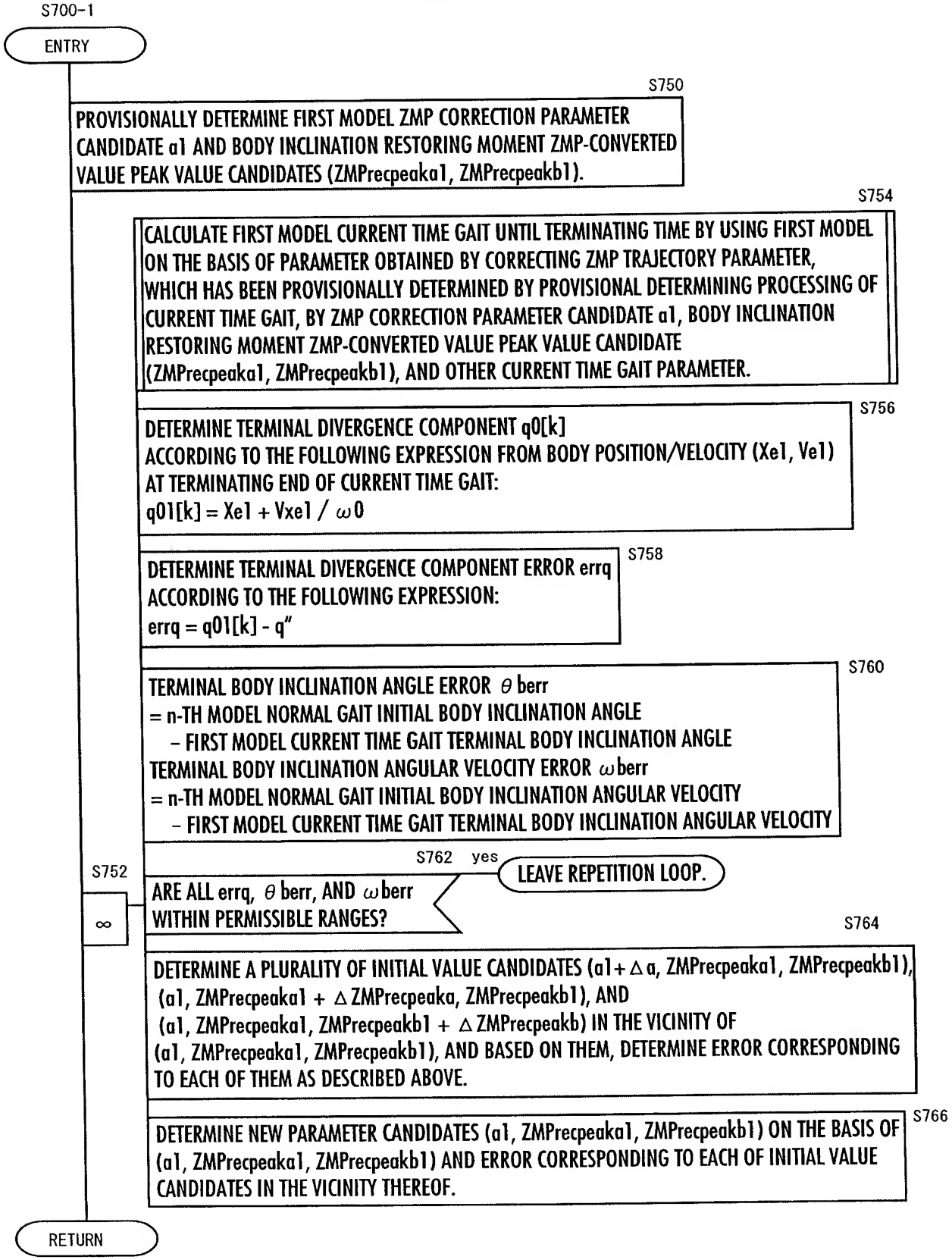

S700-1
ENTRY
S750
PROVISIONALLY DETERMINE FIRST MODEL ZMP CORRECTION PARAMETER CANDIDATE a1 AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (ZMPrecpeaka1, ZMPrecpeakb1).
S754
CALCULATE FIRST MODEL CURRENT TIME GAIT UNTIL TERMINATING TIME BY USING FIRST MODEL ON THE BASIS OF PARAMETER OBTAINED BY CORRECTING ZMP TRAJECTORY PARAMETER, WHICH HAS BEEN PROVISIONALLY DETERMINED BY PROVISIONAL DETERMINING PROCESSING OF CURRENT TIME GAIT, BY ZMP CORRECTION PARAMETER CANDIDATE a1, BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATE (ZMPrecpeaka1, ZMPrecpeakb1), AND OTHER CURRENT TIME GAIT PARAMETER.
S756
DETERMINE TERMINAL DIVERGENCE COMPONENT q0[k] ACCORDING TO THE FOLLOWING EXPRESSION FROM BODY POSITION/VELOCITY (Xe1, Ve1) AT TERMINATING END OF CURRENT TIME GAIT:
q01[k] = Xe1 + Vxe1 / ω0
S758
DETERMINE TERMINAL DIVERGENCE COMPONENT ERROR errq ACCORDING TO THE FOLLOWING EXPRESSION:
errq = q01[k] - q''
S760
TERMINAL BODY INCLINATION ANGLE ERROR θberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGLE
- FIRST MODEL CURRENT TIME GAIT TERMINAL BODY INCLINATION ANGLE
TERMINAL BODY INCLINATION ANGULAR VELOCITY ERROR ωberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGULAR VELOCITY
- FIRST MODEL CURRENT TIME GAIT TERMINAL BODY INCLINATION ANGULAR VELOCITY
S752
∞
S762
yes
ARE ALL errq, θberr, AND ωberr WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
S764
DETERMINE A PLURALITY OF INITIAL VALUE CANDIDATES (a1+Δa, ZMPrecpeaka1, ZMPrecpeakb1), (a1, ZMPrecpeaka1 + ΔZMPrecpeaka, ZMPrecpeakb1), AND (a1, ZMPrecpeaka1, ZMPrecpeakb1 + ΔZMPrecpeakb) IN THE VICINITY OF (a1, ZMPrecpeaka1, ZMPrecpeakb1), AND BASED ON THEM, DETERMINE ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S766
DETERMINE NEW PARAMETER CANDIDATES (a1, ZMPrecpeaka1, ZMPrecpeakb1) ON THE BASIS OF (a1, ZMPrecpeaka1, ZMPrecpeakb1) AND ERROR CORRESPONDING TO EACH OF INITIAL VALUE CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.23

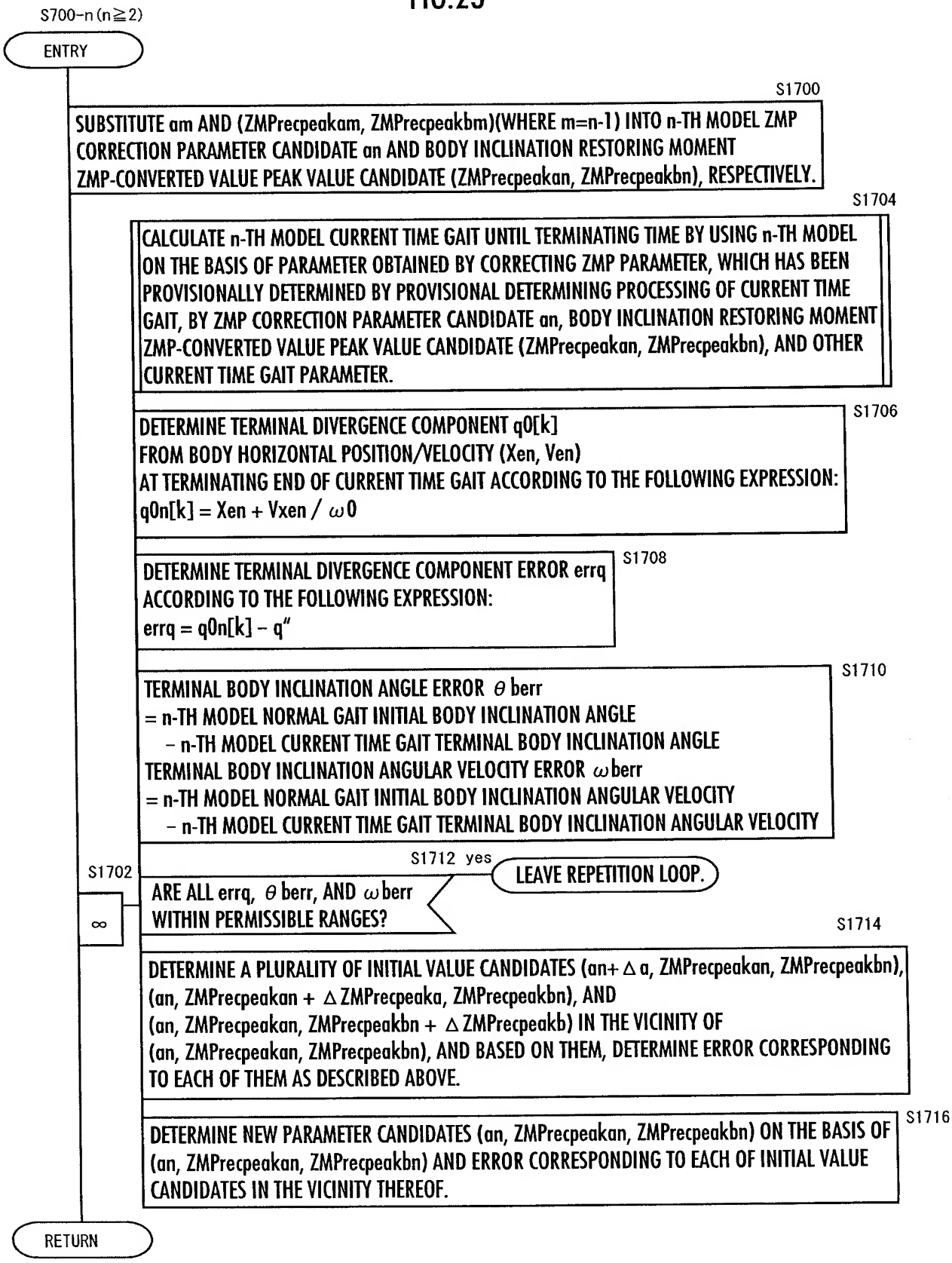

S700-n (n≧2)
ENTRY
S1700
SUBSTITUTE am AND (ZMPrecpeakam, ZMPrecpeakbm)(WHERE m=n-1) INTO n-TH MODEL ZMP CORRECTION PARAMETER CANDIDATE an AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATE (ZMPrecpeakan, ZMPrecpeakbn), RESPECTIVELY.
S1704
CALCULATE n-TH MODEL CURRENT TIME GAIT UNTIL TERMINATING TIME BY USING n-TH MODEL ON THE BASIS OF PARAMETER OBTAINED BY CORRECTING ZMP PARAMETER, WHICH HAS BEEN PROVISIONALLY DETERMINED BY PROVISIONAL DETERMINING PROCESSING OF CURRENT TIME GAIT, BY ZMP CORRECTION PARAMETER CANDIDATE an, BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATE (ZMPrecpeakan, ZMPrecpeakbn), AND OTHER CURRENT TIME GAIT PARAMETER.
S1706
DETERMINE TERMINAL DIVERGENCE COMPONENT q0[k]
FROM BODY HORIZONTAL POSITION/VELOCITY (Xen, Ven)
AT TERMINATING END OF CURRENT TIME GAIT ACCORDING TO THE FOLLOWING EXPRESSION:
q0n[k] = Xen + Vxen / ω0
S1708
DETERMINE TERMINAL DIVERGENCE COMPONENT ERROR errq
ACCORDING TO THE FOLLOWING EXPRESSION:
errq = q0n[k] - q"
S1710
TERMINAL BODY INCLINATION ANGLE ERROR θberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGLE
- n-TH MODEL CURRENT TIME GAIT TERMINAL BODY INCLINATION ANGLE
TERMINAL BODY INCLINATION ANGULAR VELOCITY ERROR ωberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGULAR VELOCITY
- n-TH MODEL CURRENT TIME GAIT TERMINAL BODY INCLINATION ANGULAR VELOCITY
S1712 yes
LEAVE REPETITION LOOP.
S1702
∞
ARE ALL errq, θberr, AND ωberr WITHIN PERMISSIBLE RANGES?
S1714
DETERMINE A PLURALITY OF INITIAL VALUE CANDIDATES (an+Δa, ZMPrecpeakan, ZMPrecpeakbn), (an, ZMPrecpeakan + ΔZMPrecpeaka, ZMPrecpeakbn), AND
(an, ZMPrecpeakan, ZMPrecpeakbn + ΔZMPrecpeakb) IN THE VICINITY OF
(an, ZMPrecpeakan, ZMPrecpeakbn), AND BASED ON THEM, DETERMINE ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S1716
DETERMINE NEW PARAMETER CANDIDATES (an, ZMPrecpeakan, ZMPrecpeakbn) ON THE BASIS OF (an, ZMPrecpeakan, ZMPrecpeakbn) AND ERROR CORRESPONDING TO EACH OF INITIAL VALUE CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.12

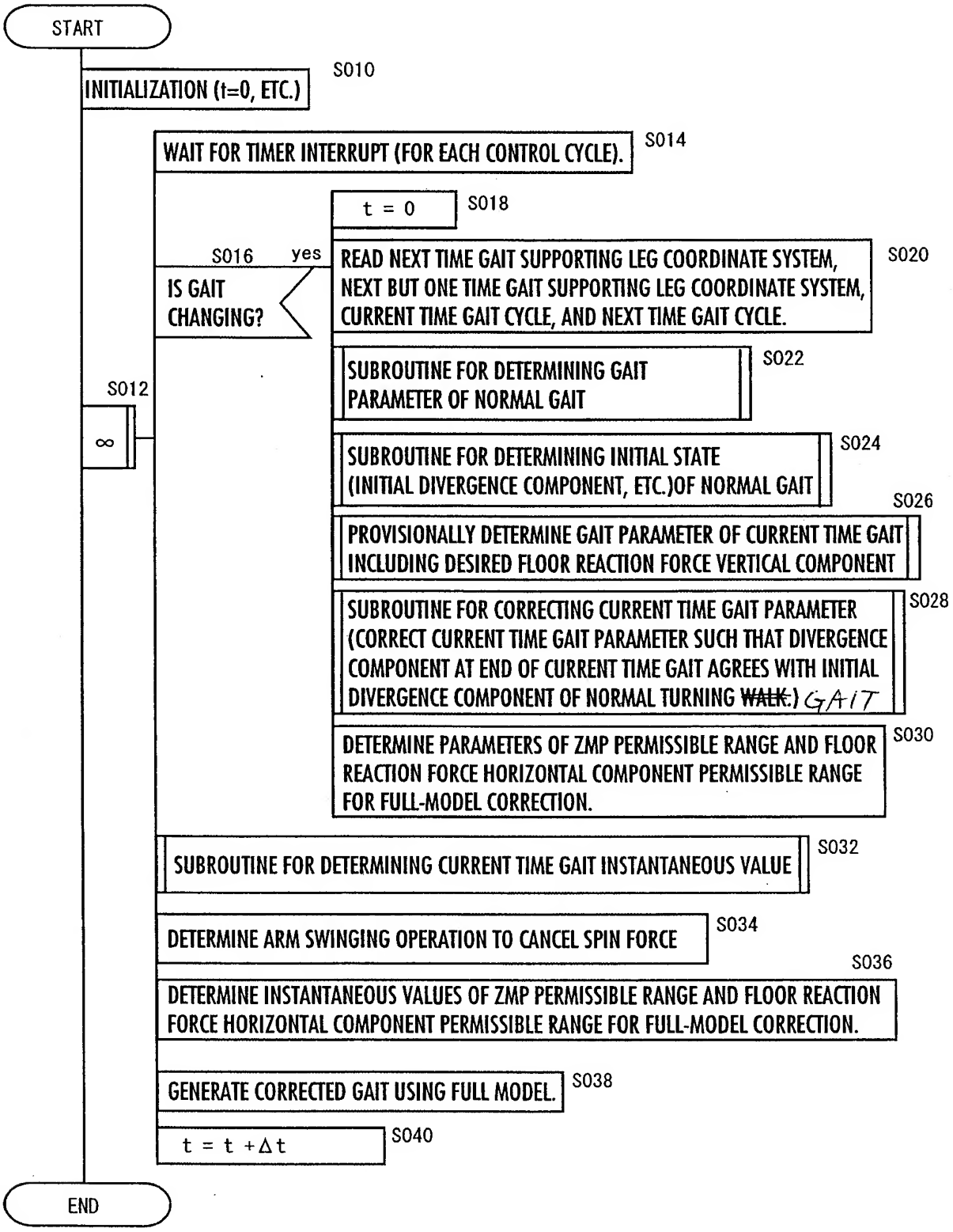

START
INITIALIZATION (t=0, ETC.)
S010
WAIT FOR TIMER INTERRUPT (FOR EACH CONTROL CYCLE).
S014
t = 0
S018
S016
yes
IS GAIT CHANGING?
READ NEXT TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, NEXT BUT ONE TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, CURRENT TIME GAIT CYCLE, AND NEXT TIME GAIT CYCLE.
S020
SUBROUTINE FOR DETERMINING GAIT PARAMETER OF NORMAL GAIT
S022
S012
∞
SUBROUTINE FOR DETERMINING INITIAL STATE (INITIAL DIVERGENCE COMPONENT, ETC.)OF NORMAL GAIT
S024
S026
PROVISIONALLY DETERMINE GAIT PARAMETER OF CURRENT TIME GAIT INCLUDING DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT
SUBROUTINE FOR CORRECTING CURRENT TIME GAIT PARAMETER (CORRECT CURRENT TIME GAIT PARAMETER SUCH THAT DIVERGENCE COMPONENT AT END OF CURRENT TIME GAIT AGREES WITH INITIAL DIVERGENCE COMPONENT OF NORMAL TURNING ~~WALK.~~) GAIT
S028
DETERMINE PARAMETERS OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
S030
SUBROUTINE FOR DETERMINING CURRENT TIME GAIT INSTANTANEOUS VALUE
S032
DETERMINE ARM SWINGING OPERATION TO CANCEL SPIN FORCE
S034
S036
DETERMINE INSTANTANEOUS VALUES OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
GENERATE CORRECTED GAIT USING FULL MODEL.
S038
t = t +Δt
S040
END

FIG.14

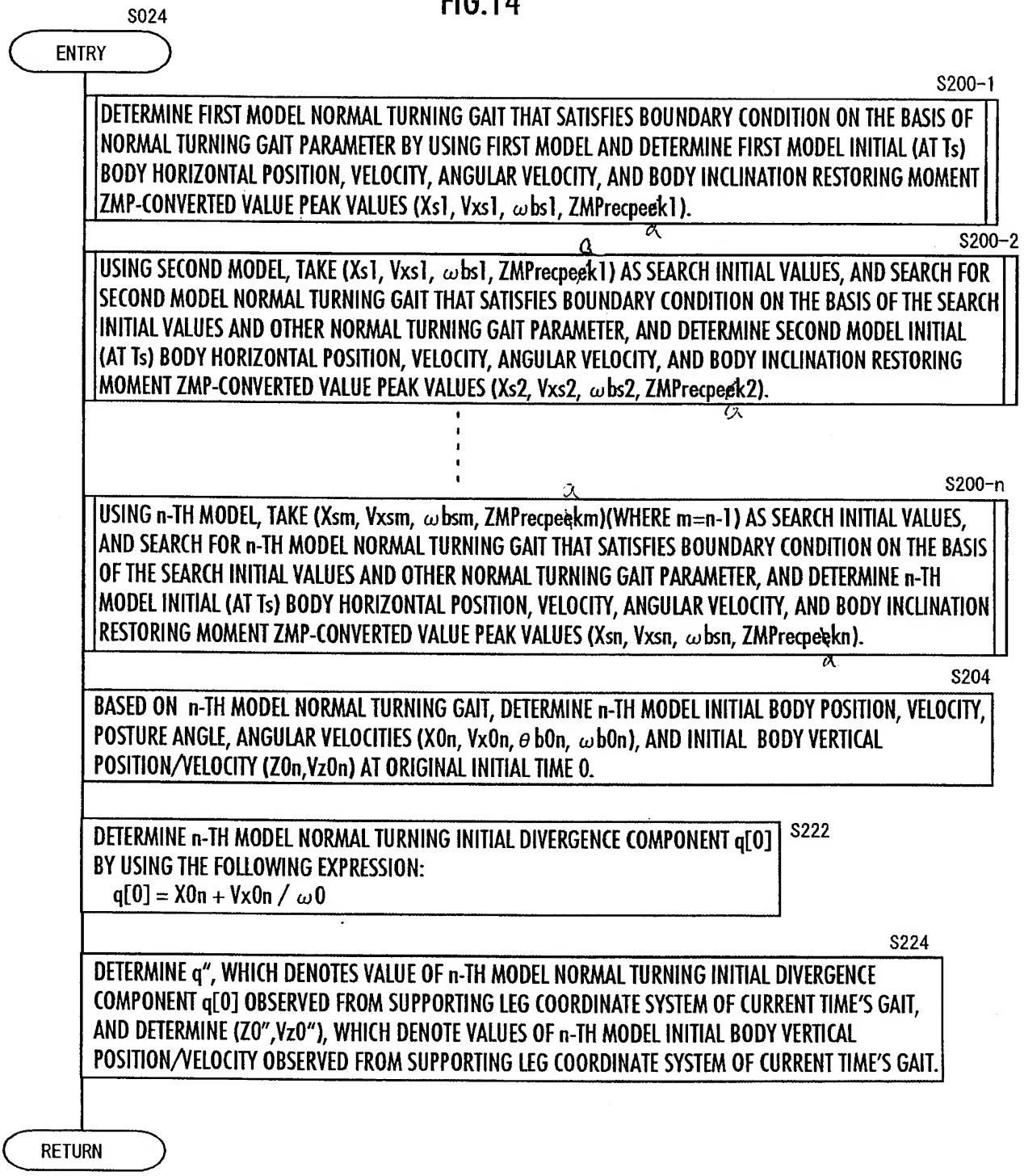

S024
ENTRY
S200-1
DETERMINE FIRST MODEL NORMAL TURNING GAIT THAT SATISFIES BOUNDARY CONDITION ON THE BASIS OF NORMAL TURNING GAIT PARAMETER BY USING FIRST MODEL AND DETERMINE FIRST MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUES (Xs1, Vxs1, ωbs1, ZMPrecpeek1).
S200-2
USING SECOND MODEL, TAKE (Xs1, Vxs1, ωbs1, ZMPrecpeek1) AS SEARCH INITIAL VALUES, AND SEARCH FOR SECOND MODEL NORMAL TURNING GAIT THAT SATISFIES BOUNDARY CONDITION ON THE BASIS OF THE SEARCH INITIAL VALUES AND OTHER NORMAL TURNING GAIT PARAMETER, AND DETERMINE SECOND MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUES (Xs2, Vxs2, ωbs2, ZMPrecpeek2).
S200-n
USING n-TH MODEL, TAKE (Xsm, Vxsm, ωbsm, ZMPrecpeekm)(WHERE m=n-1) AS SEARCH INITIAL VALUES, AND SEARCH FOR n-TH MODEL NORMAL TURNING GAIT THAT SATISFIES BOUNDARY CONDITION ON THE BASIS OF THE SEARCH INITIAL VALUES AND OTHER NORMAL TURNING GAIT PARAMETER, AND DETERMINE n-TH MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUES (Xsn, Vxsn, ωbsn, ZMPrecpeekn).
S204
BASED ON n-TH MODEL NORMAL TURNING GAIT, DETERMINE n-TH MODEL INITIAL BODY POSITION, VELOCITY, POSTURE ANGLE, ANGULAR VELOCITIES (X0n, Vx0n, θb0n, ωb0n), AND INITIAL BODY VERTICAL POSITION/VELOCITY (Z0n,Vz0n) AT ORIGINAL INITIAL TIME 0.
DETERMINE n-TH MODEL NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] BY USING THE FOLLOWING EXPRESSION:
q[0] = X0n + Vx0n / ω0
S222
S224
DETERMINE q", WHICH DENOTES VALUE OF n-TH MODEL NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME'S GAIT, AND DETERMINE (Z0",Vz0"), WHICH DENOTE VALUES OF n-TH MODEL INITIAL BODY VERTICAL POSITION/VELOCITY OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME'S GAIT.
RETURN

FIG.15

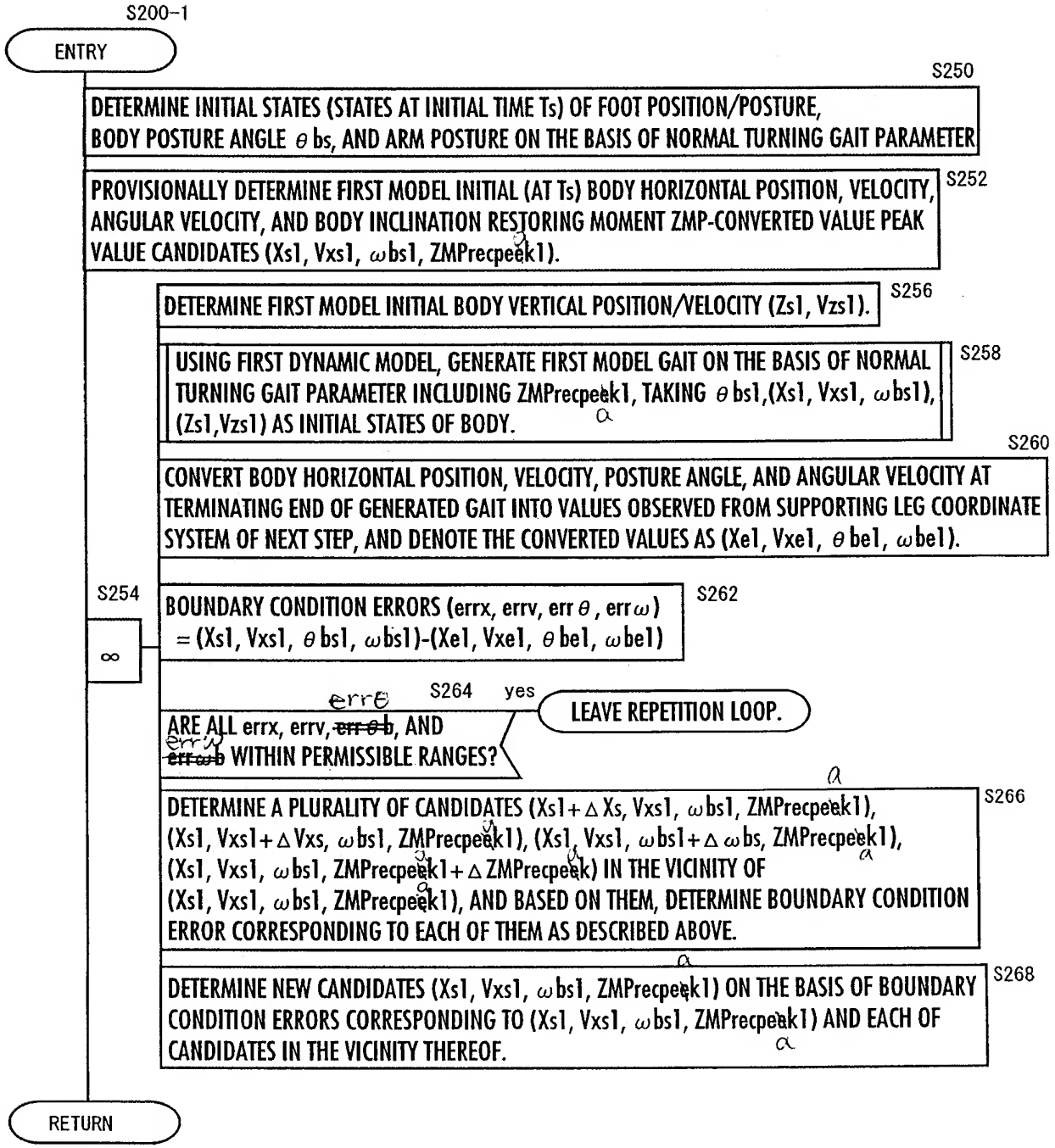

S200-1
ENTRY
S250
DETERMINE INITIAL STATES (STATES AT INITIAL TIME Ts) OF FOOT POSITION/POSTURE, BODY POSTURE ANGLE θbs, AND ARM POSTURE ON THE BASIS OF NORMAL TURNING GAIT PARAMETER
S252
PROVISIONALLY DETERMINE FIRST MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (Xs1, Vxs1, ωbs1, ZMPrecpeek1).
S256
DETERMINE FIRST MODEL INITIAL BODY VERTICAL POSITION/VELOCITY (Zs1, Vzs1).
S258
USING FIRST DYNAMIC MODEL, GENERATE FIRST MODEL GAIT ON THE BASIS OF NORMAL TURNING GAIT PARAMETER INCLUDING ZMPrecpeek1, TAKING θbs1,(Xs1, Vxs1, ωbs1), (Zs1,Vzs1) AS INITIAL STATES OF BODY.
S260
CONVERT BODY HORIZONTAL POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY AT TERMINATING END OF GENERATED GAIT INTO VALUES OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF NEXT STEP, AND DENOTE THE CONVERTED VALUES AS (Xe1, Vxe1, θbe1, ωbe1).
S254
∞
S262
BOUNDARY CONDITION ERRORS (errx, errv, errθ, errω) = (Xs1, Vxs1, θbs1, ωbs1)-(Xe1, Vxe1, θbe1, ωbe1)
S264
yes
ARE ALL errx, errv, errθb, AND errωb WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
S266
DETERMINE A PLURALITY OF CANDIDATES (Xs1+ΔXs, Vxs1, ωbs1, ZMPrecpeek1), (Xs1, Vxs1+ΔVxs, ωbs1, ZMPrecpeek1), (Xs1, Vxs1, ωbs1+Δωbs, ZMPrecpeek1), (Xs1, Vxs1, ωbs1, ZMPrecpeek1+ΔZMPrecpeek) IN THE VICINITY OF (Xs1, Vxs1, ωbs1, ZMPrecpeek1), AND BASED ON THEM, DETERMINE BOUNDARY CONDITION ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S268
DETERMINE NEW CANDIDATES (Xs1, Vxs1, ωbs1, ZMPrecpeek1) ON THE BASIS OF BOUNDARY CONDITION ERRORS CORRESPONDING TO (Xs1, Vxs1, ωbs1, ZMPrecpeek1) AND EACH OF CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.16

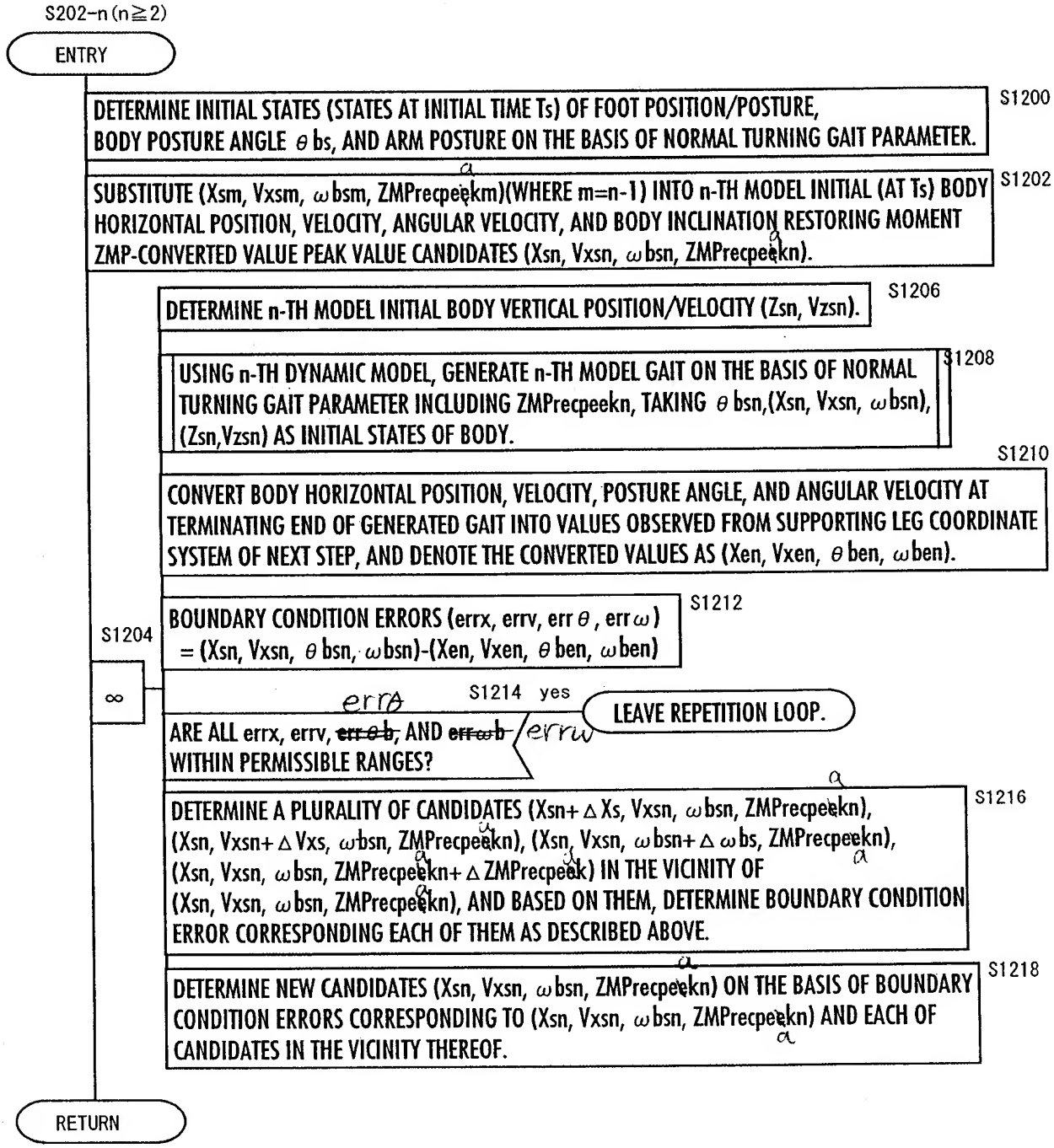

S202-n (n≧2)
ENTRY
DETERMINE INITIAL STATES (STATES AT INITIAL TIME Ts) OF FOOT POSITION/POSTURE, BODY POSTURE ANGLE θbs, AND ARM POSTURE ON THE BASIS OF NORMAL TURNING GAIT PARAMETER.
S1200
SUBSTITUTE (Xsm, Vxsm, ωbsm, ZMPrecpeekm)(WHERE m=n-1) INTO n-TH MODEL INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (Xsn, Vxsn, ωbsn, ZMPrecpeekn).
S1202
DETERMINE n-TH MODEL INITIAL BODY VERTICAL POSITION/VELOCITY (Zsn, Vzsn).
S1206
USING n-TH DYNAMIC MODEL, GENERATE n-TH MODEL GAIT ON THE BASIS OF NORMAL TURNING GAIT PARAMETER INCLUDING ZMPrecpeekn, TAKING θbsn,(Xsn, Vxsn, ωbsn), (Zsn,Vzsn) AS INITIAL STATES OF BODY.
S1208
CONVERT BODY HORIZONTAL POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY AT TERMINATING END OF GENERATED GAIT INTO VALUES OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF NEXT STEP, AND DENOTE THE CONVERTED VALUES AS (Xen, Vxen, θben, ωben).
S1210
BOUNDARY CONDITION ERRORS (errx, errv, errθ, errω) = (Xsn, Vxsn, θbsn, ωbsn)-(Xen, Vxen, θben, ωben)
S1212
S1204
∞
S1214
yes
LEAVE REPETITION LOOP.
ARE ALL errx, errv, errθb, AND errωb WITHIN PERMISSIBLE RANGES?
DETERMINE A PLURALITY OF CANDIDATES (Xsn+ΔXs, Vxsn, ωbsn, ZMPrecpeekn), (Xsn, Vxsn+ΔVxs, ωbsn, ZMPrecpeekn), (Xsn, Vxsn, ωbsn+Δωbs, ZMPrecpeekn), (Xsn, Vxsn, ωbsn, ZMPrecpeekn+ΔZMPrecpeek) IN THE VICINITY OF (Xsn, Vxsn, ωbsn, ZMPrecpeekn), AND BASED ON THEM, DETERMINE BOUNDARY CONDITION ERROR CORRESPONDING EACH OF THEM AS DESCRIBED ABOVE.
S1216
DETERMINE NEW CANDIDATES (Xsn, Vxsn, ωbsn, ZMPrecpeekn) ON THE BASIS OF BOUNDARY CONDITION ERRORS CORRESPONDING TO (Xsn, Vxsn, ωbsn, ZMPrecpeekn) AND EACH OF CANDIDATES IN THE VICINITY THEREOF.
S1218
RETURN

FIG.20

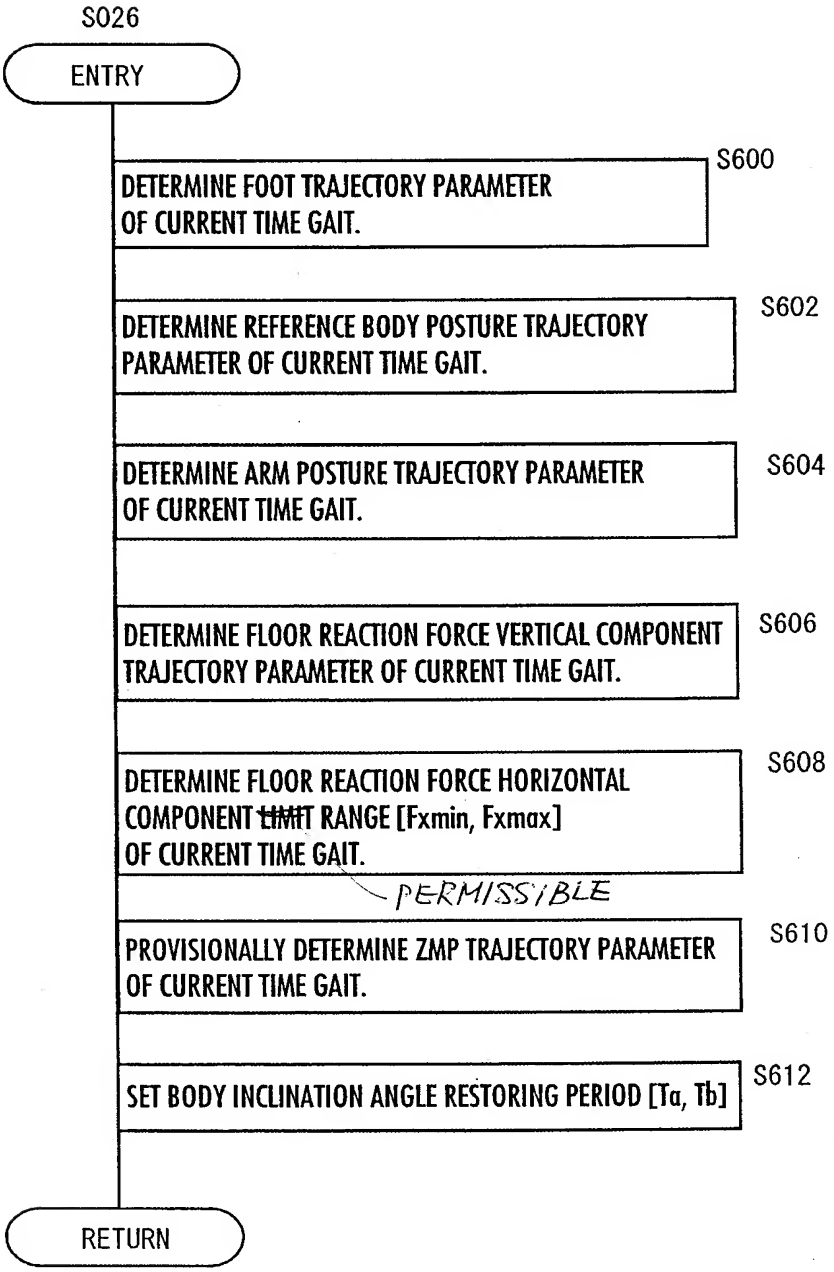

S026
ENTRY
DETERMINE FOOT TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S600
DETERMINE REFERENCE BODY POSTURE TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S602
DETERMINE ARM POSTURE TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S604
DETERMINE FLOOR REACTION FORCE VERTICAL COMPONENT TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S606
DETERMINE FLOOR REACTION FORCE HORIZONTAL COMPONENT ~~LIMIT~~ RANGE [Fxmin, Fxmax] OF CURRENT TIME GAIT.
PERMISSIBLE
S608
PROVISIONALLY DETERMINE ZMP TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S610
SET BODY INCLINATION ANGLE RESTORING PERIOD [Ta, Tb]
S612
RETURN

FIG.21

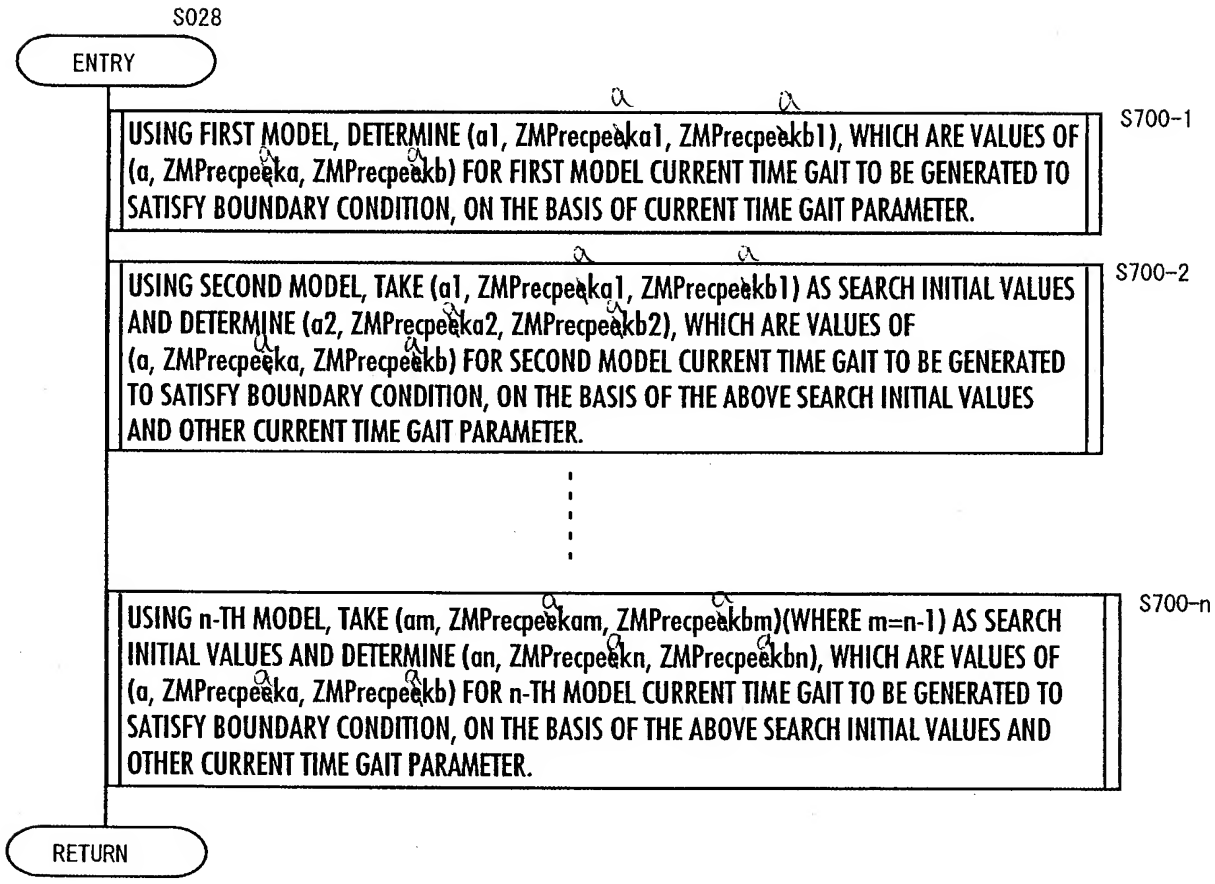

S028
ENTRY
USING FIRST MODEL, DETERMINE (a1, ZMPrecpeekaa1, ZMPrecpeekab1), WHICH ARE VALUES OF (a, ZMPrecpeeka, ZMPrecpeekb) FOR FIRST MODEL CURRENT TIME GAIT TO BE GENERATED TO SATISFY BOUNDARY CONDITION, ON THE BASIS OF CURRENT TIME GAIT PARAMETER.
S700-1
USING SECOND MODEL, TAKE (a1, ZMPrecpeekaa1, ZMPrecpeekab1) AS SEARCH INITIAL VALUES AND DETERMINE (a2, ZMPrecpeekaa2, ZMPrecpeekab2), WHICH ARE VALUES OF (a, ZMPrecpeeka, ZMPrecpeekb) FOR SECOND MODEL CURRENT TIME GAIT TO BE GENERATED TO SATISFY BOUNDARY CONDITION, ON THE BASIS OF THE ABOVE SEARCH INITIAL VALUES AND OTHER CURRENT TIME GAIT PARAMETER.
S700-2
USING n-TH MODEL, TAKE (am, ZMPrecpeekaam, ZMPrecpeekabm)(WHERE m=n-1) AS SEARCH INITIAL VALUES AND DETERMINE (an, ZMPrecpeekan, ZMPrecpeekabn), WHICH ARE VALUES OF (a, ZMPrecpeeka, ZMPrecpeekb) FOR n-TH MODEL CURRENT TIME GAIT TO BE GENERATED TO SATISFY BOUNDARY CONDITION, ON THE BASIS OF THE ABOVE SEARCH INITIAL VALUES AND OTHER CURRENT TIME GAIT PARAMETER.
S700-n
RETURN

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FIG.22

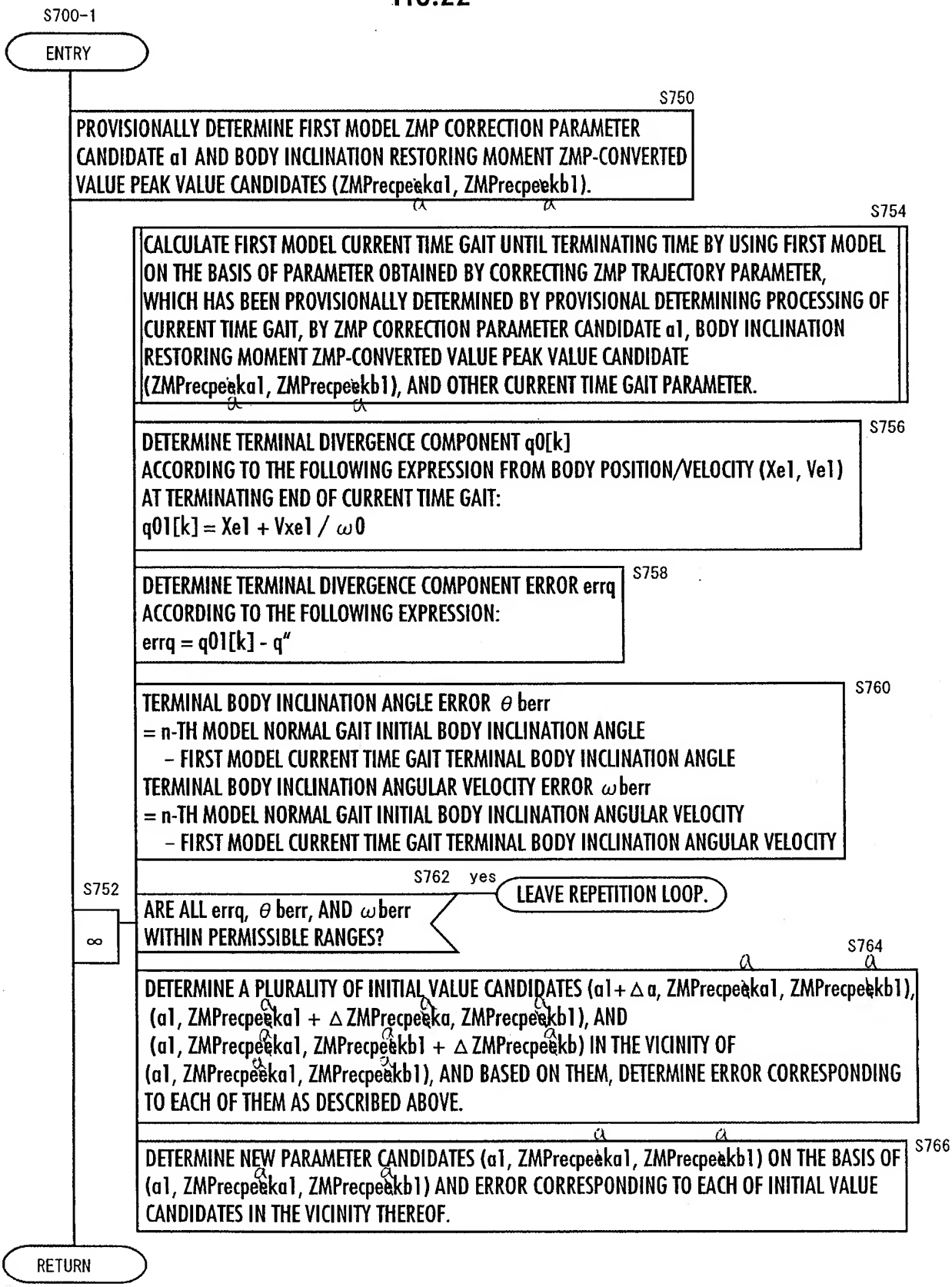
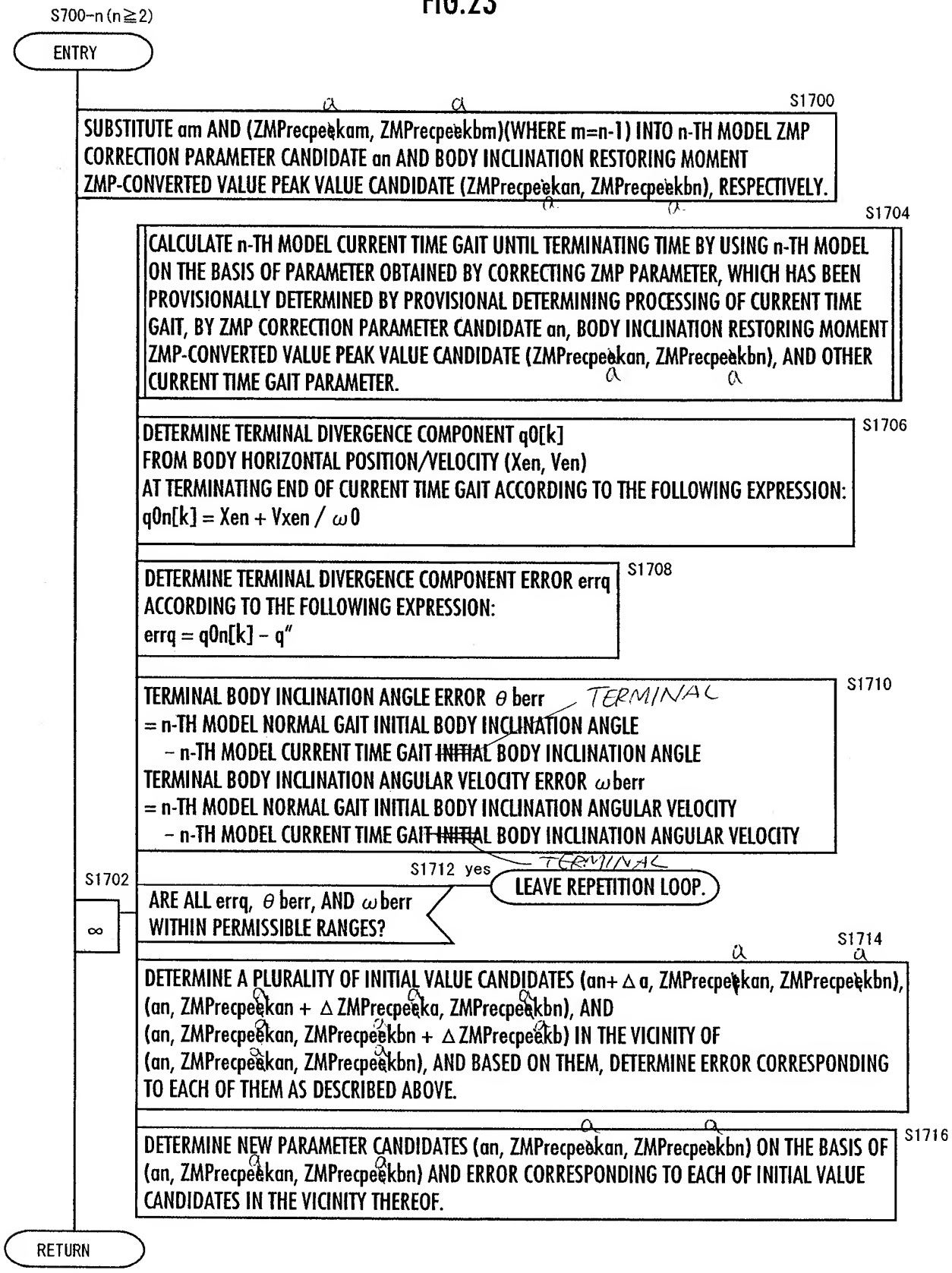

S700-1
ENTRY
S750
PROVISIONALLY DETERMINE FIRST MODEL ZMP CORRECTION PARAMETER CANDIDATE a1 AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (ZMPrecpeekaα1, ZMPrecpeekbα1).
S754
CALCULATE FIRST MODEL CURRENT TIME GAIT UNTIL TERMINATING TIME BY USING FIRST MODEL ON THE BASIS OF PARAMETER OBTAINED BY CORRECTING ZMP TRAJECTORY PARAMETER, WHICH HAS BEEN PROVISIONALLY DETERMINED BY PROVISIONAL DETERMINING PROCESSING OF CURRENT TIME GAIT, BY ZMP CORRECTION PARAMETER CANDIDATE a1, BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATE (ZMPrecpeekaα1, ZMPrecpeekbα1), AND OTHER CURRENT TIME GAIT PARAMETER.
S756
DETERMINE TERMINAL DIVERGENCE COMPONENT q0[k] ACCORDING TO THE FOLLOWING EXPRESSION FROM BODY POSITION/VELOCITY (Xe1, Ve1) AT TERMINATING END OF CURRENT TIME GAIT:
q01[k] = Xe1 + Vxe1 / ω0
S758
DETERMINE TERMINAL DIVERGENCE COMPONENT ERROR errq ACCORDING TO THE FOLLOWING EXPRESSION:
errq = q01[k] - q"
S760
TERMINAL BODY INCLINATION ANGLE ERROR θberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGLE
- FIRST MODEL CURRENT TIME GAIT TERMINAL BODY INCLINATION ANGLE
TERMINAL BODY INCLINATION ANGULAR VELOCITY ERROR ωberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGULAR VELOCITY
- FIRST MODEL CURRENT TIME GAIT TERMINAL BODY INCLINATION ANGULAR VELOCITY
S752
∞
S762 yes
ARE ALL errq, θberr, AND ωberr WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
S764
DETERMINE A PLURALITY OF INITIAL VALUE CANDIDATES (a1+Δα, ZMPrecpeekaα1, ZMPrecpeekbα1), (a1, ZMPrecpeekaα1 + ΔZMPrecpeekaα, ZMPrecpeekbα1), AND (a1, ZMPrecpeekaα1, ZMPrecpeekbα1 + ΔZMPrecpeekbα) IN THE VICINITY OF (a1, ZMPrecpeekaα1, ZMPrecpeekbα1), AND BASED ON THEM, DETERMINE ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S766
DETERMINE NEW PARAMETER CANDIDATES (a1, ZMPrecpeekaα1, ZMPrecpeekbα1) ON THE BASIS OF (a1, ZMPrecpeekaα1, ZMPrecpeekbα1) AND ERROR CORRESPONDING TO EACH OF INITIAL VALUE CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.23


S700-n (n≧2)
ENTRY
S1700
SUBSTITUTE am AND (ZMPrecpeekam, ZMPrecpeekbm)(WHERE m=n-1) INTO n-TH MODEL ZMP CORRECTION PARAMETER CANDIDATE an AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATE (ZMPrecpeekan, ZMPrecpeekbn), RESPECTIVELY.
S1704
CALCULATE n-TH MODEL CURRENT TIME GAIT UNTIL TERMINATING TIME BY USING n-TH MODEL ON THE BASIS OF PARAMETER OBTAINED BY CORRECTING ZMP PARAMETER, WHICH HAS BEEN PROVISIONALLY DETERMINED BY PROVISIONAL DETERMINING PROCESSING OF CURRENT TIME GAIT, BY ZMP CORRECTION PARAMETER CANDIDATE an, BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATE (ZMPrecpeekan, ZMPrecpeekbn), AND OTHER CURRENT TIME GAIT PARAMETER.
S1706
DETERMINE TERMINAL DIVERGENCE COMPONENT q0[k]
FROM BODY HORIZONTAL POSITION/VELOCITY (Xen, Ven)
AT TERMINATING END OF CURRENT TIME GAIT ACCORDING TO THE FOLLOWING EXPRESSION:
q0n[k] = Xen + Vxen / ω0
S1708
DETERMINE TERMINAL DIVERGENCE COMPONENT ERROR errq
ACCORDING TO THE FOLLOWING EXPRESSION:
errq = q0n[k] − q″
S1710
TERMINAL BODY INCLINATION ANGLE ERROR θberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGLE
− n-TH MODEL CURRENT TIME GAIT INITIAL BODY INCLINATION ANGLE
TERMINAL BODY INCLINATION ANGULAR VELOCITY ERROR ωberr
= n-TH MODEL NORMAL GAIT INITIAL BODY INCLINATION ANGULAR VELOCITY
− n-TH MODEL CURRENT TIME GAIT INITIAL BODY INCLINATION ANGULAR VELOCITY
TERMINAL
S1702
∞
S1712 yes
ARE ALL errq, θberr, AND ωberr WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
S1714
DETERMINE A PLURALITY OF INITIAL VALUE CANDIDATES (an+Δa, ZMPrecpeekan, ZMPrecpeekbn), (an, ZMPrecpeekan + ΔZMPrecpeeka, ZMPrecpeekbn), AND (an, ZMPrecpeekan, ZMPrecpeekbn + ΔZMPrecpeekb) IN THE VICINITY OF (an, ZMPrecpeekan, ZMPrecpeekbn), AND BASED ON THEM, DETERMINE ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S1716
DETERMINE NEW PARAMETER CANDIDATES (an, ZMPrecpeekan, ZMPrecpeekbn) ON THE BASIS OF (an, ZMPrecpeekan, ZMPrecpeekbn) AND ERROR CORRESPONDING TO EACH OF INITIAL VALUE CANDIDATES IN THE VICINITY THEREOF.
RETURN